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# The effects of split marketing on the physiology, behavior, and performance of finishing swine<sup>1,2</sup>

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**ABSTRACT:** One hundred twenty 8-wk-old barrows ( $20.3 \pm 2.0$  kg BW) were used to examine the effect of split marketing on selected behavioral, physiological and performance parameters. Pigs were assigned by weight in a randomized complete block design to one of three treatments: SM (split-marketed), six pigs/pen ( $1.83 \text{ m}^2/\text{pig}$ ); C (control), six pigs/pen ( $1.83 \text{ m}^2/\text{pig}$ ); or MC (modified control), three pigs/pen ( $3.66 \text{ m}^2/\text{pig}$ ). The heaviest half of SM animals were removed 1 wk prior to marketing penmates. Control and MC animals remained in their respective groups until marketing. Animals were videotaped during the first 72 h of the study (INITIAL), 72 h prior to (PRE), and following the removal (POST) of pigs in the SM treatment to quantify maintenance behaviors and to identify socially dominant, intermediate, and submissive pigs. A blood sample was collected from each animal upon completion of INITIAL, PRE, and POST time periods to determine neutrophil:lymphocyte ratio and plasma haptoglobin, cortisol, and corticosteroid-binding globulin (CBG) levels. Animals were weighed and feed disappearance was calculated biweekly. Tenth-rib backfat and area of the

longissimus muscle at marketing were ultrasonically evaluated on all animals. Regardless of treatment, animals were more ( $P < 0.01$ ) active (eating, standing/walking, fighting) at INITIAL than at PRE or POST times. Frequency and duration of fights per pen were less ( $P < 0.01$ ) in MC than in C or SM pigs for all periods observed. Neutrophil:lymphocyte ratio, plasma haptoglobin, and CBG levels were greater ( $P < 0.01$ ) during the INITIAL period than during the PRE or POST periods but did not differ between treatments. No treatment or time differences were detected in plasma cortisol levels. The MC pigs exhibited greater ( $P < 0.01$ ) ADFI with poorer feed efficiency compared to C or SM pigs up to split marketing. During the POST period, both MC and SM pigs had greater ( $P < 0.01$ ) ADFI with poorer ( $P < 0.01$ ) feed efficiency than C pigs. The ADG was not different among animals as a result of treatment. There were no treatment differences for any of the carcass measurements. Significant differences in performance between the treatment groups could not be attributed to any physiological or behavioral measures reported here.

Key Words: Behavior, Pigs, Stress

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## Introduction

An all-in, all-out (AIAO) system contributes to the efficient, cost-effective production of pigs. Using an AIAO system decreases the risk of disease transmission throughout the whole herd, reduces the incidence of

animal fighting, and facilitates the cleaning and disinfecting of the facilities (NPPC, 1992). However, weight variation among market animals within a pen and premiums paid by processors for uniformity constrain producers from marketing the entire pen of animals at one time and thus prevent the full use and benefits of the AIAO system.

Many large swine production operations employ split marketing of the heaviest hogs from individual pens. Split marketing can be described as the removal of the heaviest 25 to 50% of the animals from a pen, which are marketed 1 to 2 wk earlier than the remaining animals. This practice can reduce production costs by lowering total feed costs and can improve producer income because a greater number of animals can be marketed at desirable weights. Bates and Newcomb (1997) demonstrated that when the heaviest half of a pen of

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hogs were marketed 2 weeks earlier than their penmates there was significant weight gain and increased feed intake in the remaining animals. The animals remaining after split marketing were fatter than those in pens that remained intact. However, there is some concern that split marketing may disrupt an established, fixed social hierarchy within a pen, which may serve as a potential stressor to the remaining animals. Hicks et al. (1998) found that socially dominant pigs had higher ADG, lower serum globulin, and enhanced albumin:globulin ratios compared to intermediate or subordinate pigs.

The objective of this study was to assess the potential stress that split marketing may have on remaining penmates as determined by changes in selected behavioral, physiological, and performance parameters.

## Materials and Methods

### *Experimental Design and Housing*

One hundred twenty 8-wk-old, segregated early-weaned, single-source barrows (Premier Swine Breeding Systems, Michigantown, IN [T-MAX Boar  $\times$  P-100 Sow]) were allotted to four blocks of 30 pigs each. Each block of animals was delivered to the animal research facility over four consecutive weeks. All pigs were ear-tagged prior to arrival. Immediately after arrival, all pigs were weighed and randomly assigned by weight to either a split-marketed group consisting of six pigs/pen (1.83 m<sup>2</sup>/pig), a control group consisting of six pigs/pen (1.83 m<sup>2</sup>/pig), or a modified control consisting of three pigs/pen (3.36 m<sup>2</sup>/pig). Each block of the experiment had two replications. Each split-marketed pen had 50% of its heaviest barrows removed 1 wk prior to penmates. The control and modified control pigs remained in their respective pens throughout the experiment.

Animals were housed in a curtain-sided building with partially slatted concrete floor pens. Each pen contained a two-hole feeder placed on the solid portion of the floor. Animals were provided ad libitum access to a grower diet (3,410 kcal/kg ME, 15.97% CP, 0.93% lysine) until 20 wk of age (92.2 kg BW) and a finishing diet (3,452 kcal/kg ME, 14.03% CP, 0.78% lysine) until they were marketed. The diets met or exceeded NRC (1998) requirements for all nutrients. Animals were provided ad libitum access to water via one nipple waterer per pen. Daily high and low temperatures were recorded on each end of the animal facility using maximum-minimum self-registering temperature gauges (Taylor, model no. 5458, Fletcher, NC). The animal facility was illuminated continuously to facilitate behavioral data collection.

### *Behavioral Data Collection*

All animals were videotaped during the first 72 h of the study (**INITIAL**), and 72 h prior to (**PRE**) and

following the removal (**POST**) of pigs in the split-marketing treatment. Prior to videotaping, all animals were individually marked with farm animal crayon markers (All Weather Paintstik, La-Co Industries, Elk Grove Village, IL) so the animals could be distinguished on the videotapes. Behaviors were recorded continuously by 72-h (1 frame/1.6 s) time-lapse videocassette recorders (AG-6740, Panasonic, Osaka, Japan). Video cameras (Panasonic WV CP412) were suspended from the ceiling (2.3 m above the floor), permitting the filming of two pens with one camera. Scan sampling was used to collect maintenance behaviors. Each animal was viewed in one frame of videotape every 15 min to record the frequency of the following maintenance behaviors: standing/walking, sitting/lying, eating, and drinking. Standing/walking was counted when the animal was up on all four feet and either motionless or moving. A pig was considered to be eating whenever its head was in the feeder and drinking when its snout was touching the nipple waterer.

Dominance hierarchy (dominant [**DOM**], intermediate [**INT**], and subordinate [**SUB**]) was based on fight activity (McGlone et al., 1993). Fights were defined as an aggressive social interaction involving interchange of forceful or potentially harmful actions generally by some means of physical contact (Hurnick et al., 1995). When a fight was observed between two pigs, the videotape was slowed so that the length of the fight could be documented. Length of fight, pigs involved, and winner were recorded for each observed fight. A winner was defined as the pig that pursued the second pig or caused the second pig to turn away. Based on the fight data, animals were assigned to a rank by use of a dominance matrix (Martin and Bateson, 1986). The dominance matrix was determined by the number of wins and losses between each pair of pigs in the pen. For pens of six pigs, two animals each were assigned as DOM, INT, or SUB, and for pens having three animals only one animal was designated in each social rank. The design of the matrix permitted the comparison of data from the three treatments.

### *Blood Sampling and Analysis*

A blood sample (10 mL) was collected from each animal via jugular venipuncture at the end of each 72-h videotaping. Sampling began at approximately 0830 and each sample was obtained within 2 min of restraint. The split-marketed animals that were removed 1 wk prior to their penmates did not have a third blood sample collected. The blood samples were placed immediately into EDTA vacutainer tubes and gently mixed. Blood smears were made from whole blood for analysis of differential white blood cell numbers. Plasma was collected from each sample following centrifugation at 800  $\times g$  for 20 min. Plasma was aliquoted into four 1.8-mL cryogenic vials and stored at  $-20^{\circ}\text{C}$  until it was analyzed for corticosteroid-binding globulin, cortisol, and haptoglobin concentration.

**Neutrophil:Lymphocyte Ratio.** Whole-blood slides were stained using Hema-Stat 3 stain set (Protocol, Biochemical Sciences, Swedesboro, NJ) for determination of differential white blood cell numbers. One hundred white blood cells were counted by light microscopy at 100X. Leukocytes were characterized and identified as monocytes, lymphocytes, neutrophils, eosinophils, or basophils. The neutrophil:lymphocyte (**N:L**) ratio was calculated for each sample.

**Corticosteroid-Binding Globulin.** Plasma samples were analyzed for corticosteroid-binding globulin (**CBG**) concentration in duplicate using an indirect ELISA method (Kattesh and Roberts, 1993). Intra- and interassay CV were 8.7 and 11.3%, respectively.

**Cortisol.** Plasma cortisol concentration was determined using the RIA procedure of Coat-A-Count (Diagnostic Products, Los Angeles, CA). Plasma samples were analyzed in duplicate and counted for 1 min using a gamma counter (Cobra II Auto-gamma counter, Model D5005, Packard Instrument Co., Meriden, CT). Cortisol concentration was expressed as nanograms per milliliter. Intra- and interassay CV were 6.9 and 8.9%, respectively.

**Haptoglobin.** Haptoglobin was determined by a single radial immunodiffusion (**SRID**) kit (Porcine Haptoglobin Measurement Kit, Cardiotech Services, Louisville, KY). Plasma or standard (5  $\mu$ L) was added to wells of the gel plates and incubated at 37°C for 24 h, and the diameter of the precipitation ring was measured. The gelatin contained porcine anti-haptoglobin antibodies. The diameter of the ring was inversely related to the amount of plasma haptoglobin. Results were evaluated using a logarithmic regression ( $Y = -577.18 + 167.79\ln X$ ,  $r^2 = 0.99$ ) to determine haptoglobin concentration in each plasma sample using known standards. Intraassay CV of duplicate estimates was 5.1%.

### Performance Data Collection

Each animal was weighed at the beginning of the experiment, biweekly, and prior to marketing. Feed was added as needed and feed disappearance was measured biweekly to obtain feed intake. Feed disappearance was calculated as the total amount of feed added minus the amount of feed remaining at the time feeders were weighed. Average daily gain, ADFI, and feed efficiency were calculated on a per-pen basis from the weights obtained from the pigs and their feed intake biweekly.

**Ultrasonic Data.** Backfat and area of the longissimus muscle at approximately the 10th rib were measured on each animal prior to marketing using a real-time ultrasound machine (ALOKA 500V, Corometrics Medical Systems, Wallingford, CT) equipped with a 12.5-cm, 3.5-MHz linear array transducer. All images were interpreted using the AUSKEY program (Animal Ultrasound Services, Ithaca, NY). National Swine Improvement Federation (NSIF, 1997) recommended equations were used to adjust backfat and loin muscle

area to a constant weight (113 kg) and predict carcass lean using ultrasonic measures.

### Statistical Analyses

Data were analyzed as a randomized complete block design using PROC MIXED procedure of SAS (SAS Inc., Cary, NC). Block and replicate were included in the analysis model as random effects. The fixed effects of treatment (control, modified control, or split marketing), time period (INITIAL, PRE, or POST), and treatment  $\times$  time period interaction were used to analyze the physiological measures (N:L ratio, CBG, haptoglobin, and cortisol concentrations) as well as the behavioral observations of all fight data (frequency and duration of fights) and maintenance behaviors (standing/walking, sitting/lying, eating, or drinking). A log transformation was applied to corticosteroid-binding globulin, duration of fight per pen and per pig, and pig maintenance behavior data to normalize their distribution for statistical analysis. The production traits backfat, longissimus muscle cross-sectional area, percentage lean, ADG, ADFI, and feed efficiency had the fixed effect of treatment included in the model used in their analysis. Least squares means and standard errors of the means were calculated for all variables. Significant mean differences were separated by pairwise contrasts (Saxton, 1998).

## Results

Of the 120 animals that began this study, 4 were removed due to injury or sickness. The number of pigs removed from each treatment were as follows: 2/48 (control), 2/48 (split marketing), and 0/24 (modified control). One animal from the control group was removed early in the study, whereas the other three animals were removed late in the study before split marketing.

### Behavior

Scan sample data (frequency) of maintenance behaviors (standing/walking, sitting/lying, eating, drinking) was summed for the 72-h taping and analyzed on a percentage basis. Percentage of time spent performing each of the maintenance behaviors was not different ( $P > 0.10$ ) among animals due to treatment. Regardless of treatment, animals spent more ( $P < 0.01$ ) time standing/walking and less ( $P < 0.01$ ) time sitting/lying and drinking during the INITIAL compared to the PRE or POST split-marketing observation time periods (Table 1). A time  $\times$  treatment interaction was noted for drinking in that control pigs spent less ( $P < 0.01$ ) time ( $0.52 \pm 0.11\%$ ) drinking during the INITIAL period than did modified control pigs ( $1.14 \pm 0.11\%$ ) during the POST period. Split-marketed animals spent more ( $P < 0.05$ ) time sitting/lying during the PRE period ( $88.5 \pm 0.94\%$ ) than in the POST period ( $86.2 \pm 0.94\%$ ).

Frequency and duration of fighting within a pen and per pig were greater ( $P < 0.01$ ) during INITIAL than

**Table 1.** Least squares means  $\pm$  SE for maintenance behaviors (percentage of time) and frequency (number per taping period) and duration (s) of fights for pigs during the first 72 h of the experiment (INITIAL), 72 h before split marketing (PRE), and 72 h after split marketing (POST)

Measure	INITIAL	PRE	POST
Drinking	0.66 $\pm$ 0.06 <sup>a</sup>	0.90 $\pm$ 0.06 <sup>b</sup>	0.88 $\pm$ 0.06 <sup>b</sup>
Eating	7.8 $\pm$ 0.21 <sup>a</sup>	5.7 $\pm$ 0.21 <sup>b</sup>	6.1 $\pm$ 0.21 <sup>c</sup>
Sitting/lying	82.4 $\pm$ 0.54 <sup>a</sup>	88.3 $\pm$ 0.54 <sup>b</sup>	87.1 $\pm$ 0.54 <sup>c</sup>
Standing/walking	8.7 $\pm$ 0.41 <sup>a</sup>	5.2 $\pm$ 0.41 <sup>b</sup>	5.9 $\pm$ 0.41 <sup>c</sup>
Frequency of fights per pen	19.4 $\pm$ 1.1 <sup>a</sup>	4.1 $\pm$ 1.1 <sup>b</sup>	4.2 $\pm$ 1.1 <sup>b</sup>
Duration of fights per pen	1,324.1 $\pm$ 266.4 <sup>a</sup>	43.1 $\pm$ 266.4 <sup>b</sup>	59.0 $\pm$ 266.4 <sup>b</sup>
Frequency of fights per pig	3.7 $\pm$ 0.21 <sup>a</sup>	0.73 $\pm$ 0.21 <sup>b</sup>	0.98 $\pm$ 0.21 <sup>b</sup>
Duration of fights per pig	419.7 $\pm$ 105.8 <sup>a</sup>	7.7 $\pm$ 105.8 <sup>b</sup>	15.4 $\pm$ 105.8 <sup>b</sup>

<sup>a,b,c</sup>Means within a row with uncommon superscripts differ ( $P < 0.01$ ).

PRE or POST periods (Table 1). Regardless of observation period, animals in the modified control group fought less ( $P < 0.01$ ) frequently and for shorter ( $P < 0.01$ ) periods than split-marketed or control pigs when compared on a per-pen basis (Table 2). On a per-pig basis, modified control pigs had fewer and shorter fights than split-marketed pigs but were similar in duration and frequency to control pigs. During the INITIAL period, animals in split-marketed and control groups fought more ( $P < 0.01$ ) than modified control pigs (25.4  $\pm$  2.0 and 23.7  $\pm$  1.8 vs 9.0  $\pm$  1.9 fights/ videotaping period). During the PRE period, split-marketed pigs displayed more ( $P < 0.01$ ) fights than modified control pigs (6.9  $\pm$  2.0 vs 1.0  $\pm$  1.9 fights/videotaping period), whereas control pigs (4.3  $\pm$  1.8 fights/videotaping period) were not different ( $P > 0.10$ ) from the other groups. During the POST period, modified control pigs fought less ( $P < 0.01$ ) than control pigs (1.5  $\pm$  1.9 vs 7.6  $\pm$  1.8 fights/videotaping period) whereas split-marketed pigs (3.6  $\pm$  2.0 fights/videotaping period) were not different from the other groups. Social status had no effect on any of the physiological or performance measures as reported in this study.

### Pig Performance

Pigs within each treatment had similar body weights at their final weight (Table 3). Likewise, ADG was not different among animals over the course of the study. Modified control pigs exhibited greater ( $P < 0.01$ ) ADFI and poorer ( $P < 0.01$ ) feed efficiency than control or

split-marketed pigs from the beginning of the study until split marketing. Following split marketing, both modified control and split-marketed pigs had greater ( $P < 0.01$ ) ADFI with lower ( $P < 0.01$ ) feed efficiency than control pigs. There were no ultrasonically measured 10th-rib backfat or area of the longissimus muscle differences due to treatment, although control pigs tended to be leaner ( $P = 0.08$ ) than modified control pigs, whereas split-marketed pigs were not different from the other two groups (Table 3).

### Physiological Measures

The N:L ratio, plasma haptoglobin, and CBG concentrations were greater ( $P < 0.01$ ) during the INITIAL period than during the PRE or POST periods (Table 4). The higher N:L ratio during the INITIAL period resulted from a significant ( $P < 0.01$ ) increase in neutrophil and a concurrent decrease in lymphocyte numbers. Plasma cortisol concentration was not different as a result of treatment or time of sampling. Overall, CBG concentration tended ( $P = 0.06$ ) to be higher in modified control pigs (37.2  $\pm$  2.1  $\mu$ g/mL) than in control pigs (31.6  $\pm$  1.7  $\mu$ g/mL).

### Discussion

Animals were more active during the INITIAL period than during PRE or POST split marketing as determined by the amount of time they spent standing/walking, fighting, and eating. An increased activity level is

**Table 2.** Least squares means  $\pm$  SE for overall frequency (number per taping period) and duration (s) of fights for control, modified control, and split-marketed pigs

Measure	Control	Modified control	Split-marketed
Frequency of fights per pen	11.8 $\pm$ 1.3 <sup>a</sup>	3.8 $\pm$ 1.4 <sup>b</sup>	12.0 $\pm$ 1.5 <sup>a</sup>
Duration of fights per pen	734.6 $\pm$ 256.8 <sup>a</sup>	111.6 $\pm$ 272.3 <sup>b</sup>	580.0 $\pm$ 291.1 <sup>a</sup>
Frequency of fights per pig	2.0 $\pm$ 0.24 <sup>c,d</sup>	1.3 $\pm$ 0.25 <sup>c</sup>	2.2 $\pm$ 0.27 <sup>d</sup>
Duration of fights per pig	122.4 $\pm$ 102.2	37.2 $\pm$ 108.4	283.2 $\pm$ 115.9

<sup>a,b</sup>Means within a row with uncommon superscripts differ ( $P < 0.01$ ).

<sup>c,d</sup>Means within a row with uncommon superscripts differ ( $P < 0.05$ ).

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**Table 3.** Least squares means  $\pm$  SE for performance measures of control, modified control, and split-marketed pigs from d 0 of study until split marketing (Up to SM), 2 wk prior to split marketing (2 wk pre SM), and 1 wk following split marketing (Post SM)

Measure	Control	Modified control	Split-marketed
Final weight, kg	119.1 $\pm$ 2.4	121.5 $\pm$ 2.4	119.9 $\pm$ 2.4
ADG, kg/d			
Up to SM	0.85 $\pm$ 0.02	0.88 $\pm$ 0.02	0.85 $\pm$ 0.02
2 wk pre SM	0.88 $\pm$ 0.03	0.93 $\pm$ 0.03	0.94 $\pm$ 0.03
Post SM	0.95 $\pm$ 0.04	0.96 $\pm$ 0.04	1.01 $\pm$ 0.04
Feed intake, kg/d			
Up to SM	1.99 $\pm$ 0.05 <sup>a</sup>	3.00 $\pm$ 0.05 <sup>b</sup>	1.94 $\pm$ 0.05 <sup>a</sup>
2 wk pre SM	2.26 $\pm$ 0.18 <sup>a</sup>	2.93 $\pm$ 0.17 <sup>b</sup>	2.24 $\pm$ 0.18 <sup>a</sup>
Post SM	2.02 $\pm$ 0.45 <sup>a</sup>	3.59 $\pm$ 0.45 <sup>b</sup>	3.92 $\pm$ 0.45 <sup>b</sup>
Gain:feed ratio			
Up to SM	0.43 $\pm$ 0.01 <sup>a</sup>	0.30 $\pm$ 0.01 <sup>b</sup>	0.44 $\pm$ 0.01 <sup>a</sup>
2 wk pre SM	0.40 $\pm$ 0.02 <sup>a</sup>	0.32 $\pm$ 0.02 <sup>b</sup>	0.43 $\pm$ 0.02 <sup>a</sup>
Post SM	0.50 $\pm$ 0.05 <sup>a</sup>	0.26 $\pm$ 0.05 <sup>b</sup>	0.30 $\pm$ 0.05 <sup>b</sup>
Backfat, cm <sup>c</sup>	2.36 $\pm$ 0.10	2.52 $\pm$ 0.12	2.34 $\pm$ 0.10
Loin eye area, cm <sup>2c</sup>	44.6 $\pm$ 0.97	42.9 $\pm$ 1.2	43.2 $\pm$ 0.98
Lean, % <sup>c</sup>	52.9 $\pm$ 0.66	51.8 $\pm$ 0.75	52.5 $\pm$ 0.66

<sup>a,b</sup>Means within a row with uncommon superscripts differ ( $P < 0.01$ ).

<sup>c</sup>Backfat depth = 10th-rib backfat depth; loin eye area = 10th-rib loin eye area. Measurements were taken by real-time ultrasound prior to marketing.

normal when first placing pigs in a pen because animals investigate their new environment and penmates. They also establish a social hierarchy by fighting vigorously within the first 24 h of mixing and usually have a stable social hierarchy established within 48 h (McGlone, 1985, 1986; Morrow-Tesch et al., 1994). The greater frequency and duration of fighting observed during the INITIAL period may explain why standing/walking behavior was highest during this time period. Maintenance behaviors were analyzed irrespective of fighting and all fights occurred while standing/walking.

Increased eating during the INITIAL period could be age-related; pigs eat more meals when younger, but as they grow larger they eat larger meals less frequently (Bigelow and Houpt, 1988; Augspurger et al., 2000). Also, feed consumption is inversely related to environmental temperature, as reported for growing-finishing pigs grown at constant temperatures between 5 and 30°C (Hahn and Nienaber, 1988). During the INITIAL time period, the average high temperature in the animal facility was 27°C, compared to 30°C during the

PRE and POST periods. Ideally, floor temperature should range from 15°C to 18°C during the finishing phase for optimal growth and feed consumption (Hahn and Nienaber, 1988).

During PRE and POST time periods, pigs were less active, as evidenced by increased sitting/lying behavior. Pigs also fought less, indicative of a fixed social hierarchy; fights were replaced with threats. Ewbank and Meese (1971) found no increase in fighting after removal of one pig from a pen of eight that had a stable social hierarchy. They also found that if a dominant animal was removed, the second-highest-ranking animal moved into the dominant position. Overall, in the present study, control pigs and split-marketed pigs fought more often and for longer periods of time than did modified control pigs. The greater density among animals in control and split-marketed groups could have contributed to the increased fighting. As group size increases, it is common for the dominance hierarchy to become more complex, lending itself to increased

**Table 4.** Least squares means  $\pm$  SE for physiological measures of stress in blood from pigs after the first 72 h of the experiment (INITIAL), 72 h before split marketing (PRE), and 72 h after split marketing (POST)

Measure	INITIAL	PRE	POST
Neutrophil:lymphocyte ratio	0.55 $\pm$ .02 <sup>a</sup>	0.34 $\pm$ .02 <sup>b</sup>	0.35 $\pm$ .02 <sup>b</sup>
Haptoglobin, $\mu$ g/mL	978.8 $\pm$ 50.4 <sup>a</sup>	732.0 $\pm$ 51.6 <sup>b</sup>	769.6 $\pm$ 54.6 <sup>b</sup>
Corticosteroid-binding globulin, $\mu$ g/mL	11.3 $\pm$ 0.52 <sup>a</sup>	15.5 $\pm$ 0.56 <sup>b</sup>	14.9 $\pm$ 0.60 <sup>b</sup>
Cortisol, ng/mL	48.5 $\pm$ 3.6	52.4 $\pm$ 3.7	49.2 $\pm$ 3.9

<sup>a,b</sup>Means within a row with uncommon superscripts differ ( $P < 0.01$ ).

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fighting in order for the hierarchy to become stable (Craig, 1986).

Drinking behavior was also increased during the PRE and POST observation periods. Higher temperatures cause an animal to consume or at least to have more contact with water, which could explain why the animals spent more time drinking during PRE and POST periods. More time drinking may have resulted from an increase in the water requirement of the pigs as related to size. Also, it is difficult to detect drinking behavior differences because it has a high day-to-day variation (Bigelow and Houpt, 1988). Other researchers have found that pigs do not always consume water when their mouths are touching the waterer (McBride and James, 1964; Bryant and Ewbank, 1974). Alternatively, the pigs may have been playing with the waterer after being forced away from the feeder as a form of displacement behavior (McBride and James, 1964) or as a means of evaporative cooling.

Up until split marketing, pigs on the modified control treatment exhibited greater ADFI than control or split-marketed pigs without substantial weight gains. Brumm et al. (1996) reported that barrows in lower-density pens usually consume more feed without a significant increase in body weight, resulting in poorer feed efficiency. This could be because animals with increased space are more active and thereby consume more feed. Brumm et al. (1996) also found that barrows up to 136 kg BW had no improvement in productivity if provided more than 1 m<sup>2</sup>/pig. Growing-finishing swine provided up to 1 m<sup>2</sup>/pig have increased daily gain and feed disappearance with less of an effect on feed efficiency (Kornegay and Notter, 1984). In the present study, modified control pigs had two feeder holes per three pigs, whereas control and split-marketed pigs had two feeder holes per six pigs until split marketing, at which time the remaining animals in the split-marketed treatment had space equal to that of the modified control group. The discrepancy in feeder space likely did not account for the increased feed intake by the modified control pigs. Increasing or decreasing feeder space beyond what is typically provided for nursery pigs has shown no improvement or depression of daily gain, daily feed intake, or feed efficiency (Lindemann et al., 1987).

The remaining animals in the split-marketed pens following split marketing had greater ADFI without an increase in ADG compared to control but not modified control groups. Bates and Newcomb (1997) demonstrated that when the heaviest 50% of the animals within a pen were marketed 2 wk earlier than their penmates, there were significant weight gains and increased feed intake in the remaining animals. However, feed efficiency in their study was not improved. Based on the results of Lindemann et al. (1987), the increased average daily feed intake for the remaining pigs in the split-marketed pens was probably more a function of increased pen space per pig rather than increased feeder space. Bryant and Ewbank (1974) found that

decreasing pen density increased feed intake while number of feeder holes remained the same between treatments. However, in their study, there were no significant differences in feed conversion or ADG. They suggested that an increased stocking density reduces an individual's ability to move about its living space and, as the pigs grow and further reduce their area for maneuvering, visits to the feeder and(or) waterer may become more difficult.

Tenth-rib backfat thickness, cross-sectional area of the longissimus muscle, and percentage lean were not different among treatments. Likewise, the physiological measures taken in this study did not reflect that the pigs were experiencing a chronic stress. However, density can contribute to productivity in pigs. When pigs were given 0.62 m<sup>2</sup>/pig, 0.72 m<sup>2</sup>/pig, or 0.93 m<sup>2</sup>/pig and marketed at 107 kg, the leanest carcasses with the smallest backfat depth occurred in pigs maintained at 0.62 m<sup>2</sup>/pig (Bates and Newcomb, 1997). Limited data have demonstrated that there is a slight improvement in carcass backfat depth as space is restricted due to decreased daily feed intake (PIC, 1997). The present study found no such improvement in productivity even though the treatments in this study could be considered crowded after the pigs reached 68 kg (NPPC, 1992).

Cortisol concentration was not different between animals regardless of treatment or time. Only one blood sample was collected in the morning during each sampling time, which other studies have shown may not be sufficient to detect differences unless multiple samples are collected over the course of a day. Differences in cortisol levels due to circadian rhythm or stress can be detected when collecting more than one sample, especially by collecting morning and afternoon samples (Kattesh et al., 1995; Zanella et al., 1998). Similar to the present study, Alexander and Irvine (1998) also found no change in cortisol in socially stressed horses by taking one morning sample. Cortisol concentrations in the present study were rather high, but the blood samples were taken at 0800 when the circadian rhythm of cortisol is at its highest level, and the animals had just been moved down an alleyway to be weighed before the blood sample was collected. Cortisol levels have been found to be higher after rousing a pen of pigs (Cook et al., 1998).

Elevation of CBG concentration during the INITIAL period compared to PRE or POST periods may be an age-related phenomenon. Age-related differences in CBG concentration have been found with levels greater at 40 d of age compared to pigs 125 d of age (our unpublished observations). Overall, CBG levels for control pigs were lower than those for modified control or split-marketed pigs. CBG concentration decreases in stressed animals (Kattesh et al., 1995; Alexander and Irvine, 1998), which would suggest that animals in the control treatment were stressed. The reason for this is not clear, except that the control animals were maintained at the greatest density for the entire trial, whereas modified control pigs were maintained at half

the density of the control treatment for the entire trial. Split-marketed pigs had the same density as control pigs until the last week of the trial, when they had the equivalent density of the modified control treatment, but there was no time  $\times$  treatment interaction for CBG.

The N:L ratio was greater during the INITIAL than during PRE or POST periods. Stull et al. (1999) found that 28- and 56-d-old pigs had greater N:L ratio that decreased up to 168 d of age. The authors suggested that the higher N:L ratio in younger pigs may be attributed to the stress of weaning, mixing of litters, partial influence of glucocorticoids, pathogen challenge, or nutritional adaptations rather than age. In the present study, N:L ratio was weakly correlated with cortisol concentration ( $r = 0.25$ ;  $P < 0.05$ ). Although N:L ratio in the present study was greatest during the INITIAL period, other studies have found even higher N:L ratios with other stressors such as transport or heat or cold stress (McGlone et al., 1993; Hicks et al., 1998).

Haptoglobin was also elevated during the INITIAL period compared to PRE and POST periods. These results are similar to those reported by Eurell et al. (1992), who found that haptoglobin values peaked in pigs at 6 to 8 wk of age and decreased up to 13 wk of age. The peak haptoglobin values reported by Eurell et al. (1992) were much lower than those found in the present study for similar-aged animals, suggesting that the INITIAL animals were experiencing a stress response. However, it must be considered that during the INITIAL period the animals were fighting vigorously, which has been shown to cause tissue damage (Tan and Shackleton, 1990). Increased tissue damage can cause an inflammatory response that can increase plasma haptoglobin levels (Eurell et al., 1992).

### Implications

Marketing the heaviest 50% of the pigs in a pen 1 wk earlier than their penmates resulted in poorer feed efficiency in the remaining animals. This reduction in pig performance could not be attributed to changes in behavioral or physiological measures as employed in our study. In this experiment, the maximum number of animals penned together was six due to facility limitations. Typically, 25 to 30 hogs or more are penned together in commercial grow-finish facilities. Additionally, only barrows were used in the present study and pens of all gilts or mixed-sex pens may not respond in a similar fashion. Social dynamics and physiological effects may or may not be different in a typical commercial setting compared to the penning arrangements employed in this study.

### Literature Cited

- Alexander, S. L., and C. H. G. Irvine. 1998. The effect of social stress on adrenal axis activity in horses: The importance of monitoring corticosteroid-binding globulin capacity. *J. Endocrinol.* 157:425–432.
- Augsburger, N. R., M. Ellis, D. N. Hamilton, B. F. Wolter, J. L. Beverly, and E. R. Wilson. 2000. The feed intake behavior of the progeny of two sire lines monitored by a computerized feed intake recording system. *J. Anim. Sci.* 78(Suppl. 1):240 (Abstr.).
- Bates, R. O., and M. D. Newcomb. 1997. Removal of market ready pen mates improved growth rate of remaining pigs. *J. Anim. Sci.* 75(Suppl. 1):247 (Abstr.).
- Bigelow, J. A., and T. R. Houpt. 1988. Feeding and drinking patterns in young pigs. *Physiol. Behav.* 43:99–109.
- Brumm, M. C., and NCR-89 Committee on Management of Swine. 1996. Effect of space allowance on barrow performance to 136 kilograms body weight. *J. Anim. Sci.* 74:745–749.
- Bryant, M. J., and R. Ewbank. 1974. Effects of stocking rate upon the performance, general activity and ingestive behaviour of groups of growing pigs. *Br. Vet. J.* 130:139–149.
- Cook, N. J., J. Chang, R. Borg, W. Robertson, and A. L. Schaefer. 1998. The effects of natural light on measures of meat quality and adrenal responses to husbandry stressors in swine. *Can. J. Anim. Sci.* 78:293–300.
- Craig, J. V. 1986. Measuring social behavior: Social dominance. *J. Anim. Sci.* 62:1120–1129.
- Eurell, T. E., D. P. Bane, W. F. Hall, and D. J. Schaeffer. 1992. Serum haptoglobin concentration as an indicator of weight gain in pigs. *Can. J. Vet. Res.* 56:6–9.
- Ewbank, R., and G. B. Meese. 1971. Aggressive behavior in groups of domesticated pigs on removal and return of individuals. *Anim. Prod.* 13:685–693.
- Hahn, G. L., and J. A. Nienaber. 1988. Performance in carcass composition of growing-finishing swine as thermal environmental selection guides. In: *Proc. 3rd Int. Livest. Environmental Symp.*, Toronto, Canada. pp 93–100.
- Hicks, T. A., J. J. McGlone, C. S. Whisnant, H. G. Kattesh, and R. L. Norman. 1998. Behavioral, endocrine, immune, and performance measures for pigs exposed to acute stress. *J. Anim. Sci.* 76:474–483.
- Hurnick, J. F., A. B. Webster, and P. B. Siegel. 1995. *Dictionary of Farm Animal Behavior*, 2nd ed. Iowa State University Press, Ames.
- Kattesh, H. G., M. E. Brown-Crutchfield, J. L. Wolf II, and J. F. Schneider. 1995. Effect of restricted movement on the physiology and behavior of swine. *Tenn. Agric. Sci.* 176:31–35.
- Kattesh, H. G., and M. P. Roberts. 1993. Age related changes in plasma concentrations of porcine corticosteroid binding globulin (pCBG) as determined by an enzyme-linked immunosorbent assay (ELISA). *J. Anim. Sci.* 71(Suppl. 1):234 (Abstr.).
- Kornegay, E. T., and D. R. Notter. 1984. Effects of floor space and number of pigs per pen on performance. *Pig News Info.* 5:23–33.
- Lindemann, M. D., E. T. Kornegay, J. B. Meldrum, G. Schurig, and F. C. Gwazdauskas. 1987. The effect of feeder space allowance on weaned pig performance. *J. Anim. Sci.* 64:8–14.
- Martin, P., and P. Bateson. 1986. *Measuring Behavior: An Introductory Guide*. Cambridge University Press, Cambridge, U.K.
- McBride, G., and J. W. James. 1964. Social behavior of domestic animals. IV. Growing pigs. *Anim. Prod.* 6:129–139.
- McGlone, J. J. 1985. A quantitative ethogram of aggressive and submissive behaviors in recently regrouped pigs. *J. Anim. Sci.* 61:559–565.
- McGlone, J. J. 1986. Influence of resources on pig aggression and dominance. *Behav. Processes* 12:135–144.
- McGlone, J. J., J. L. Salak, E. A. Lumpkin, R. I. Nicholson, M. Gibson, and R. L. Norman. 1993. Shipping stress and social status effects on pig performance, plasma cortisol, natural killer cell activity, and leukocyte numbers. *J. Anim. Sci.* 71:888–896.
- Morrow-Tesch, J. L., J. J. McGlone, and J. L. Salak-Johnson. 1994. Heat and social stress effects on pig immune measures. *J. Anim. Sci.* 72:2599–2609.
- NPPC. 1992. *Swine Care Handbook*. National Pork Producers Council, Des Moines, IA.
- NRC. 1998. *Nutrient Requirements of Swine*. 10th ed. National Academy Press, Washington, DC.

- NSIF. 1997. Guidelines for Uniform Swine Improvement Programs (rev. ed.). National Swine Improvement Federation, USDA Program AID 1157, Washington, DC.
- PIC. 1997. PIC USA Production Tech. Update. vol. 2. Available at <http://www.pic.com/usa>. Accessed March 1, 2000.
- Saxton, A. 1998. A macro for converting mean separation output to letter groupings in PROC MIXED. In: Proc. 23rd SAS Users Group International Conference, SAS Inst. Inc., Cary, NC. pp 1243–1246.
- Stull, C. L., C. J. Kachulis, J. L. Farley, and G. J. Koenig. 1999. The effect of age and teat order on  $\alpha$ 1-acid glycoprotein, neutrophil-to-lymphocyte ratio, cortisol, and average daily gain in commercial growing pigs. *J. Anim. Sci.* 77:70–74.
- Tan, S. S. L., and D. M. Shackleton. 1990. Effects of mixing unfamiliar individuals and of azaperone on the social behavior of finishing pigs. *Appl. Anim. Behav. Sci.* 26:157–168.
- Zanella, A. J., P. Brunner, J. Unshelm, M. T. Mendl, and D. M. Broom. 1998. The relationship between housing and social rank on cortisol,  $\beta$ -endorphin and dynorphin (1–13) secretion in sows. *Appl. Anim. Behav. Sci.* 59:1–10.

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